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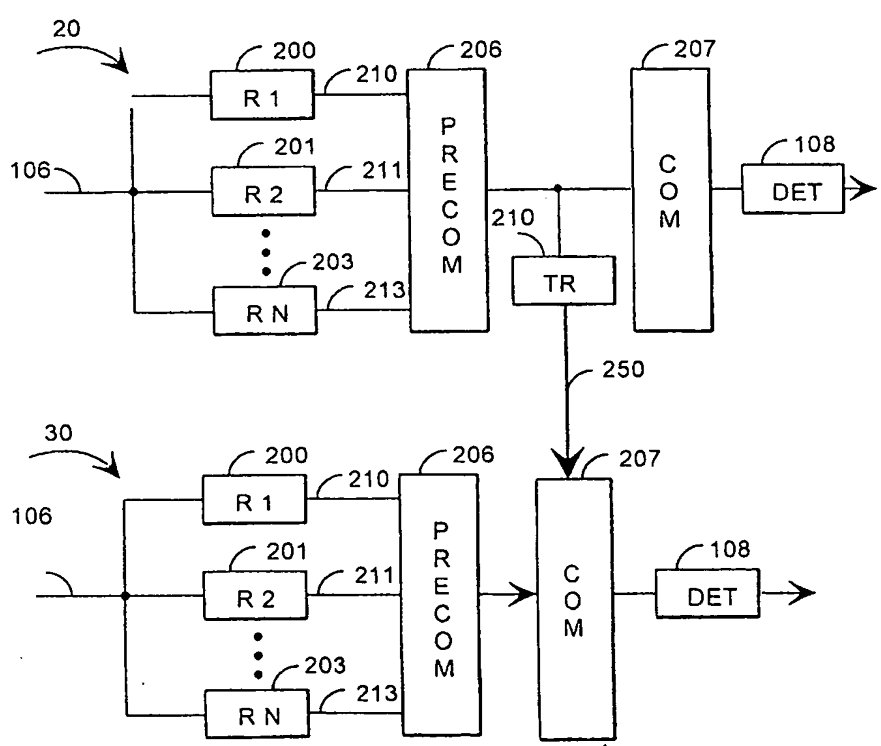
(54) Title: A METHOD FOR COMBINING SIGNALS, AND A RECEIVER

(57) Abstract

The invention relates to a method for combining signals, and a receiver implemented on the RAKE principle. The receiver comprises a number of branches by means of which it receives a signal. The receiver comprises a precombining means which as need be combines signals received via the branches of the receiver, a transmitting means for transmitting the precombined signals as need be further to a second receiver, and a combining means for combining the signals received via the receiver branches with the precombined signal.



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A METHOD FOR COMBINING SIGNALS, AND A RECEIVER

FIELD OF THE INVENTION

The invention relates to a method for combining signals, employed by a cellular radio system in a softer hand-off situation.

PRIOR ART

A receiver operating on the RAKE principle has a number of branches each capable of synchronizing to a different signal component. Consequently, the receiver is able to receive several signals simultaneously. RAKE receivers are used particularly in CDMA receivers.

A CDMA (Code Division Multiple Access) system is a multiple access method which is based on spread spectrum technology and whose application in cellular radio systems has lately been initiated along with the earlier FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access) technologies. The CDMA technology has several advantages over the earlier methods, such as spectral efficiency and simple frequency planning.

In a CDMA method, the narrow-band data signal of the user is multiplied by a spreading code of much wider bandwidth to a relatively wide band. In the known experimental systems, the bandwidths used include, for example, 1.25 MHz, 10 MHz and 25 MHz. In the multiplying process, the data signal spreads to the whole band used. All users transmit simultaneously by using the same frequency band. A separate spreading code is employed for each connection between a base station and a mobile station, and the signals from the users can be identified from one another in the receivers on the basis of the spreading code of each connection. An attempt is made for choosing the spreading codes so that they are mutually orthogonal, i.e. they do not correlate with each other.

In a typical radio system, such as a cellular radio system, a subscriber terminal communicates with one base station only. In e.g. the CDMA system a subscriber terminal may, however, also communicate with several base stations at the same time. In a prior art soft hand-off, an unbroken connection is maintained with a base station regardless of the hand-off. In such a hand-off, the base station typically changes. Also known in prior art is a softer hand-off in which the base station does not change but the sector of the base station employed does. The soft and softer hand-offs are referred to as make-before-break type of hand-offs, which means that a new connection is

established for a subscriber terminal before the previous base station connection is cut. In neither of these hand-offs will the frequency band employed change.

Cellular radio systems comprise cells that have been divided in sectors. A softer hand-off may be implemented e.g. by placing in each sector a RAKE receiver which receives a signal. The signals received by the RAKE receivers placed in the sectors are routed via a bus to a combiner which carries out diversity combining for the signals. Diversity combining reduces the disadvantages caused by fading of a signal. In practice, however, routing of signals to a combiner via a bus is difficult to implement because the implementation requires a very fast bus. In a cellular radio system, a base station receives a signal from the radio path by means of an antenna. Connecting the signals received by the antenna further to a RAKE receiver causes additional problems. Problems are met particularly in case of a high capacity CDMA base station, which signifies a large number of signals to be connected.

Attempts have been made to overcome the aforementioned problems by grouping the RAKE receivers in a suitable manner. Such grouping has been accomplished with the receivers receiving antenna signals of a specific sector only. The grouping, however, has brought on new problems. A problem has been met in combining the signals, received by the RAKE receivers, between receiver groups in different sectors. Combining signals has presented problems especially in softer hand-off situations particularly in high-capacity CDMA receivers. There have been attempts to overcome the problems met in the aforementioned situation by routing the signals to a combiner carrying out the diversity combining. The routing has, however, produced similar rate problems relating to the bus capacity as mentioned above.

A softer hand-off may be implemented e.g. by detecting a signal first at a RAKE receiver, after which, instead of diversity combining, substantially the best diversity signal is chosen. This method, however, has not contributed to a good enough performance. A second alternative to carry out a hand-off is optimal combining of RAKE signals and signal detection. However, optimal signal combining is difficult to implement. The outputs of a Walsh-Hadamard transformation typically used at RAKE receivers are connected to the combiner e.g. via the bus structure. In addition, the implementation is further impeded by the fact that the bus structure must be possible to configure to different kinds of

softer hand-off situations dynamically. To implement the solution described above in practice has been difficult and problematic since very high rate requirements are set for the bus. In practice, the combining has been performed by direct summing of the signals of the RAKE receivers. In addition, the signals may have been weighted in different ways in the summing.

CHARACTERISTICS OF THE INVENTION

It is consequently an object of the present invention to implement a RAKE receiver by means of which signal combining is carried out optimally in a softer hand-off situation.

This object is achieved by a method for combining signals, employed by a cellular radio system comprising at least two receivers; a first receiver and a second receiver, which receive a signal, the receiver being implemented on the RAKE principle and comprising a number of branches by means of which the receiver receives a signal, the method comprising the steps of precombining the signals received via the receiver branches, transmitting the precombined signals of the first receiver as need be further to the second receiver and combining said precombined signal with the precombined signal of said second receiver.

The object is additionally achieved by a method for combining signals, employed by a cellular radio system comprising at least two receivers; a first receiver and a second receiver, which receive a signal, the receiver being implemented on the RAKE principle and comprising a number of branches by means of which the receiver receives a signal, the method comprising the steps of precombining the signals received via the branches of the first receiver, transmitting the precombined signal as need be further to the second receiver and combining said precombined signal with the signals received via the branches of the second receiver.

The invention further relates to a receiver implemented on the RAKE principle and comprising a number of branches by means of which the receiver receives a signal, and the receiver further comprising a precombining means for precombining the signals received via the receiver branches, a transmitting means for transmitting the precombined signals as need be further to a second receiver, and a combining means for combining said precombined signals.

The invention further relates to a receiver implemented on the RAKE principle and comprising a number of branches by means of which the

receiver receives a signal, and the receiver further comprising a precombining means which as need be precombines the signals received via the receiver branches, a transmitting means for transmitting the precombined signals as need be further to a second receiver, and a combining means for combining the signals received via the branches with the precombined signal.

The receiver structure described above makes it possible to employ the receiver in both a low and high capacity CDMA base station. The receiver operates in different modes of operation, and the receiver carries out the diversity combining. The diversity combining is distributed to be performed in different locations on the basis of the mode of operation being employed. The receiver enables optimal reception during normal reception. In a softer hand-off situation, reception is almost optimal. Distributing of diversity combining makes it possible to combine the receivers with a bus structure whose rate does not place restrictions to practical implementation of the bus structure. The solution enables combining all the RAKE branches of the receiver with one combiner. It is possible to use one combiner in normal combining of signals of one RAKE receiver. Further, in a softer hand-off situation, it is possible to employ one combiner in combining a signal transmitted from more than one sectors of a cell in the cellular radio system.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be described with reference to the examples in the accompanying drawings, in which

Figure 1 illustrates a spread-spectrum receiver of the invention by means of a schematic block diagram,

Figures 2 and 3 illustrate in closer detail the structure of the receiver according to the invention,

Figure 4 shows two RAKE receivers according to the invention, which are interconnected with a bus, and

Figure 5 represents a cellular radio network in which the receiver according to the invention is employed.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

At first, a general description will be offered of a receiver 20 according to the invention with the aid of the block diagram in Figure 1. The figure shows a receiver of a subscriber terminal, but the inventive receiver may naturally be located at e.g. a base station, too. The receiver 20 according to

the invention comprises an antenna 100 which receives a signal to be applied to radio frequency parts 102 in which the signal is transformed to an intermediate frequency. From the radio frequency parts 102, the signal is fed to an analog-to-digital converter 104 in which the signal is sampled and converted to a digital form. The converted signal 106 is applied to a detecting means 108 at which the channel parameters of the signal and the desired symbols contained by the signal are detected.

The signal detected at the receiver of Figure 1 is applied to a channel decoder 110 and a speech decoder 112, after which the decoded signal is applied to a loudspeaker 114. If a data terminal is in question, the speech decoder is obviously replaced with some other decoder. Further, if a base station receiver is in question, the signal is applied after the channel coding block to other parts of the receiver. The receiver of the invention additionally comprises a control processor 116 which controls the operation of the other parts. The receiver according to the invention naturally comprises other components as well, such as filters and amplifiers, which is obvious for a person skilled in the art, but for reasons of clarity they are not shown in the figure.

Next, the structure of the inventive receiver implemented on the RAKE principle is examined in more detail by means of the exemplary block diagram of Figure 2. The receiver of the figure comprises four RAKE branches 200 - 203. In addition, the receiver comprises a precombiner 206 and a combiner 207. The RAKE branches are connected to the precombiner 206 with lines 210 - 213. The combiners 206 and 207 are functionally coupled to the branches 200 - 203. The branches are connected to the same input bus 106. Each branch independently receives signals allocated to the branch 200 - 203 in question, the signals being delayed with respect to one another. The RAKE branches 200 - 203 form an output signal from the signal by employing e.g. a Walsh-Hadamard transformation, the output signal being then applied to the precombiner 206 via the lines 210 - 213. In practice, the branches 200 - 203 are correlators that are capable of synchronizing to the signal received. Each branch receives a signal independently, irrespective of the other branches. In a softer hand-off mode, the combiner 207 illustrated in the figure serves as the actual signal combiner.

Figure 3 illustrates a receiver comprising a combining means 206. The combining means 206 combines signals received via the branches 200 -

203. The combining means 206 may also combine precombined signals received from another receiver.

Figure 4 shows two receivers 20, 30 that are interconnected by an H bus 250. The receiver arrangement illustrated in the figure is based on distributed signal combining. Compared to concentrated combining, distributed combining makes it possible to reduce the rate employed at the H bus 250. The receiver according to the invention is capable of operation in different modes. Such modes of the receiver include e.g. normal mode, softer hand-off transmission mode and softer hand-off receiving mode. Distributed signal combining according to the invention enables optimal signal combining in a softer hand-off situation. In the normal mode, the precombiner 206 only combines the signals of the branches 200 - 203 of the RAKE receiver in question. Following this, the combined signal is detected by the detecting means 108. In addition to detection, the detecting means 108 also decodes the signal.

In Figure 4, both the receivers 20, 30 receive a signal and, by the precombining means 206, precombine the signals received. The receiver 20 comprises a transmission means 210 which transmit the precombined signals to the receiver 30. The receiver 30 may also comprise a transmitting means 210. The receiver 20 transmits a signal to the receiver 30 via the bus 250. In the solution according to the figure, the receiver 30 receives by the combining means 207 a signal transmitted by the receiver 20. The signal precombined by the receiver 20 is in this case not necessarily transmitted to the combiner 207 of the receiver 20.

The precombining means 206 selects from the signals received e.g. the ones whose quality is adequate to be precombined. The selection may be based on signal to noise ratio, bit error ratio, measuring the energy of the signal, or on measurements similar to those mentioned. The precombining means 206 may, in addition to the precombining, also combine the precombined signals, whereby a separate combiner 207 is not necessarily required. The solution set forth in Figure 4 may also be realized with the receiver 20 first transmitting the signals it has precombined to the receiver 30. Following this, the combining means 206 of the receiver 30 combines the signals received via its branches 200-203 with the signal transmitted from the receiver 20.

Figure 5 shows a cellular radio system comprising a subscriber terminal 50 which has a simultaneous connection to both the RAKE receivers 20, 30. The cellular radio system further comprises a base station 60. It is

assumed in the following that the receivers 20, 30 are located in different sectors. It is further assumed that the subscriber terminal 50 and the receiver 30 are located in the same sector. The receiver 30 receives signals transmitted by the subscriber terminal 50, which are precombined in the precombining means 206, 207 of the receiver 30. The receiver 30 transmits the signals it has precombined via the H bus 250 to the receiver 20 to be combined. In this situation, the receiver 30 is in the softer hand-off transmitting mode. In this case, the precombined signals received by the receiver 20 are combined with the precombined signal transmitted by the receiver 30. Signal combining, thus, is in this case carried out in the combiner 207 or 206 of the receiver 20. In the solution according to the figure, the subscriber terminal 50 comprises a RAKE receiver 40. The subscriber terminal 40 is in practice e.g. a mobile phone. In the solution according to the figure, the RAKE receivers 20, 30 communicate with the base station 60. The RAKE receiver 30 may also be located at e.g. the base station 60.

The receiver 20 also combines signals received by its different branches 200 - 203. The receiver 20 receives the precombined signal transmitted by the receiver 30. In the above situation, the receiver 20 is in the softer hand-off receiving mode. Following this, the receiver 20 combines the precombined signal with the signal obtained from the different branches 200 - 203 of said receiver 20. In the situation above, the receiver 30 operates in the softer hand-off transmitting mode. In both the softer hand-off modes, the signals are combined in a distributed manner. The distributed combining is carried out by precombining the signals, after which the precombined signals are transmitted to be further combined with a signal received e.g. by another receiver.

The H bus interconnecting the RAKE receivers may be designed in many different ways. The bus may be e.g. a 64-bit-wide parallel bus operating in time division principle. The RAKE receivers write results obtained in the precombining process to the bus. In addition, the receivers read out said results from the bus. It is assumed that a cell of a cellular radio network is divided into e.g. six sectors, and 30 RAKE receivers are placed in each of the sectors. If the receiver takes samples that are 8 bits long from the signal 4800 times per second, the data rate of the combining will be 2.4576 Mbit/s. In case all the 180 receivers in the cell are coupled to the same serial mode bus, the total rate of the bus will be 442.368 Mbit/s. If the bus is 64 bits wide, the bus rate would be

6.912 MHz. If, in turn, the bus is 128 bits wide, the bus rate is 3.456 MHz. The aforementioned bus rates can be achieved in practice.

The RAKE receiver according to the invention can be implemented e.g. on one ASIC circuit. The receiver may also be used at base stations requiring high capacity. However, it is not always justifiable to construct a high-capacity, multisector base station system at locations that require high capacity. The receiver according to the invention makes it possible to establish a multisector base station system by combining base station systems containing fewer cells.

Although the invention is in the above described with reference to the example of the accompanying drawings, it is obvious that the invention is not restricted thereto but it may be modified in various ways within the inventive idea of the attached claims

CLAIMS

1. A method for combining signals, employed by a cellular radio system comprising at least two receivers; a first receiver and a second receiver, which receive a signal, the receiver being implemented on the RAKE principle and comprising a number of branches by means of which the receiver receives a signal, the method comprising the steps of

precombining the signals received via the receiver branches,

transmitting the precombined signals of the first receiver as need be further to the second receiver, and

combining said precombined signal with the precombined signal of said second receiver.

2. A method for combining signals, employed by a cellular radio system comprising at least two receivers; a first receiver and a second receiver, which receive a signal, the receiver being implemented on the RAKE principle and comprising a number of branches by means of which the receiver receives a signal, the method comprising the steps of

precombining the signals received via the branches of the first receiver,

transmitting the precombined signal as need be further to the second receiver, and

combining said precombined signal with the signals received via the branches of the second receiver.

3. A method as claimed in claim 1 or 2, used in a softer hand-off situation.

4. A method as claimed in claim 1 or 2, wherein the combined signal formed from the precombined signals is detected and decoded.

5. A method as claimed in claim 1 or 2, wherein each branch receives a signal independently, irrespective of the other branches, and wherein the received signals are diversity-combined.

6. A method as claimed in claim 1 or 2, wherein the signal is transformed, after reception, by a Walsh-Hadamard transformation, or a transformation similar to said transformation.

7. A method as claimed in claim 1 or 2, which is employed by a cellular radio system consisting of cells that have been divided into sectors provided with receivers, and the method comprising the step of transmitting

the precombined signals to be combined with signals received via branches of a receiver located in another sector.

8. A method as claimed in claim 1 or 2, wherein the receivers are interconnected by a bus, and wherein the precombined signals of the first receiver are transmitted along the bus to a second receiver.

9. A method as claimed in claim 1 or 2, employed by a cellular radio system consisting of at least two base stations whose receivers receive a signal from their respective sectors, wherein the base stations are combined so that it is possible for the base station also to receive a signal received by another base station.

10. A receiver implemented on the RAKE principle and comprising a number of branches by means of which the receiver receives a signal, and the receiver further comprising

a precombining means for precombining the signals received via the receiver branches,

a transmitting means for transmitting the precombined signals as need be further to a second receiver, and

a combining means for combining said precombined signals.

11. A receiver implemented on the RAKE principle and comprising a number of branches by means of which the receiver receives a signal, and the receiver further comprising

a precombining means which as need be precombines the signals received via the receiver branches,

a transmitting means for transmitting the precombined signals as need be further to a second receiver, and

a combining means for combining the signals received via the branches with the precombined signal.

12. A receiver as claimed in claim 10 or 11, comprising a detecting means for detecting and decoding the signal combined by the combining means.

13. A receiver as claimed in claim 10 or 11, wherein the precombining means precombines the signals received by means of the branches in case the precombined signals are transmitted to be combined with a signal received by a branch of another receiver.

14. A receiver as claimed in claim 10 or 11, wherein the combining means receives the signals from the branches of said receiver, and combines said signals with the precombined signal.

15. A receiver as claimed in claim 10 or 11, comprising a detecting means for detecting and decoding the signal combined by the combining means, said detecting means preventing detection and decoding of the signal in said receiver in case the transmitting means transmits the precombined signal to another receiver for combining.

16. A receiver as claimed in claim 10 or 11, wherein the precombining means and the combining means serve as diversity combiners, and wherein each branch of the receiver receives a signal independently, irrespective of the other branches.

17. A receiver as claimed in claim 10 or 11, wherein a branch transforms a signal received by a Walsh-Hadamard transformation or a transformation similar to said transformation.

Fig. 1

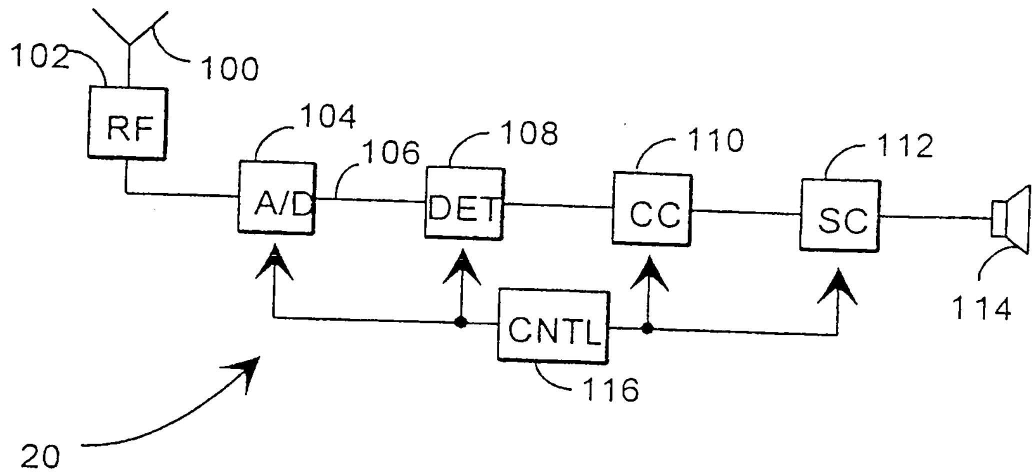


Fig. 2

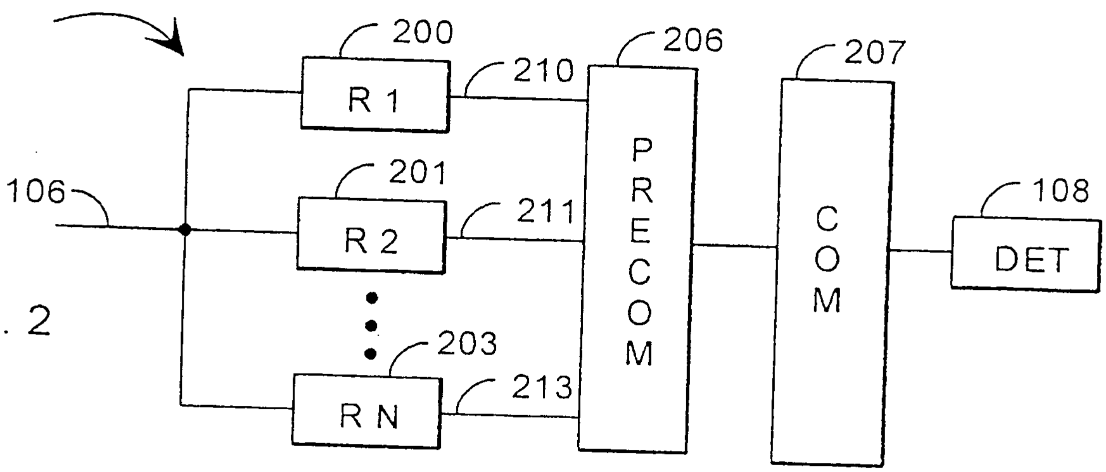
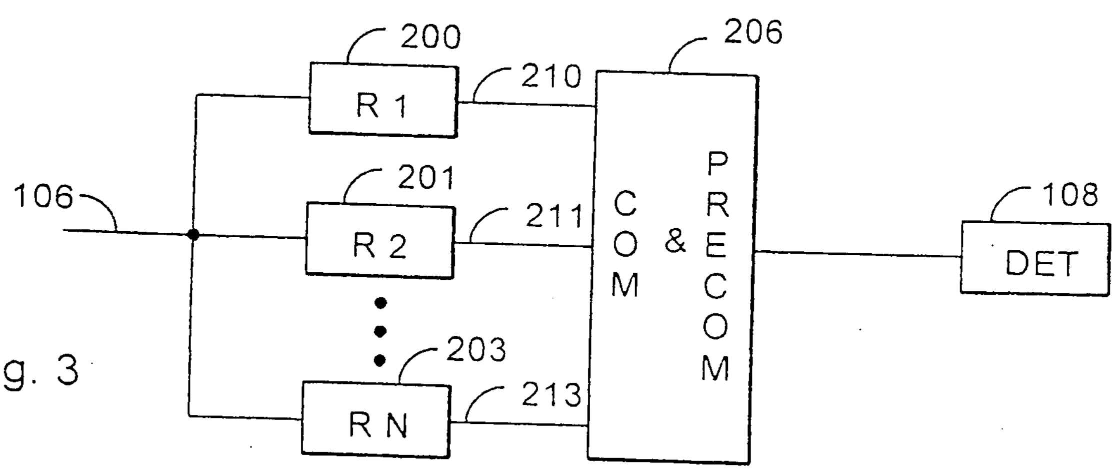


Fig. 3



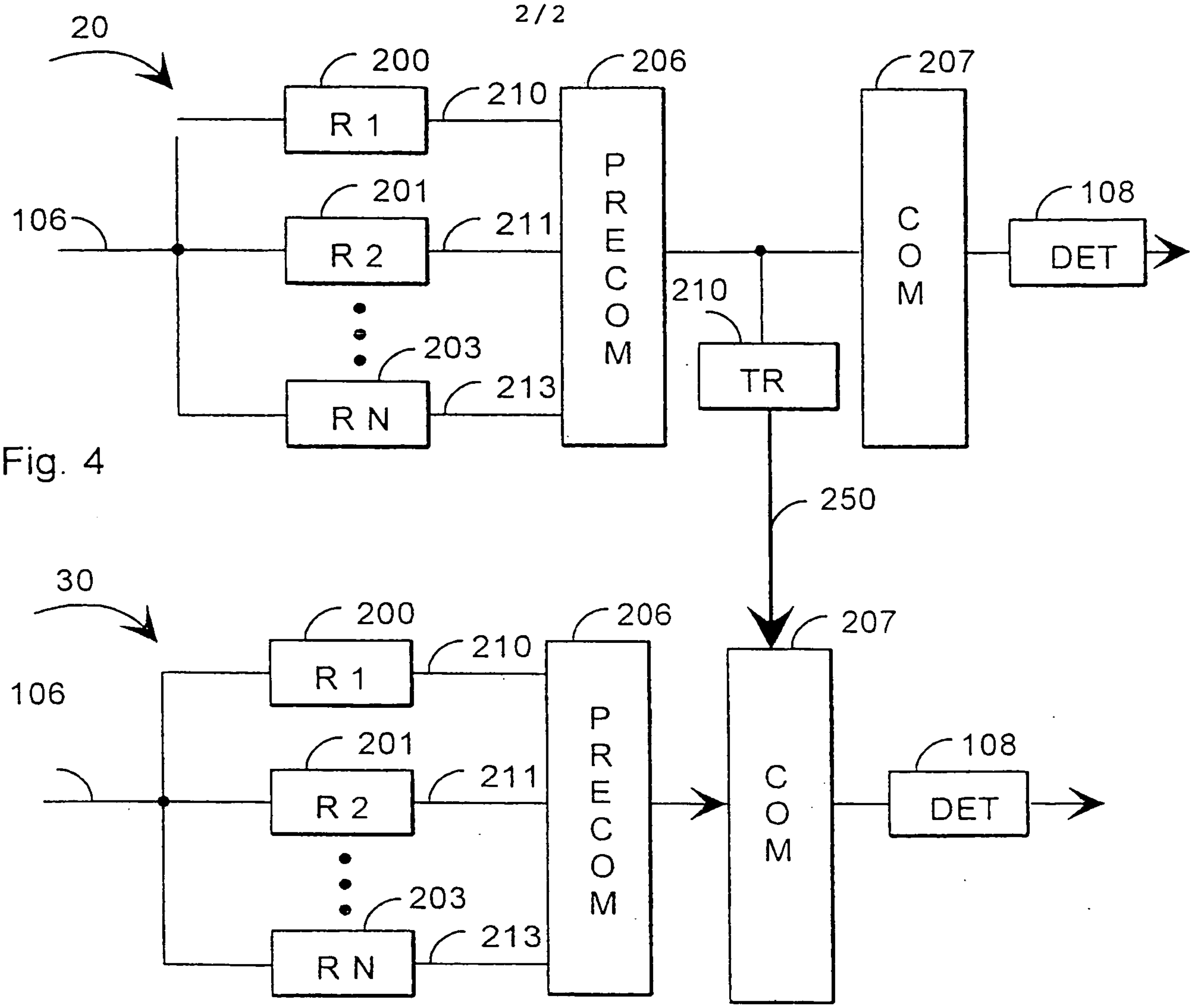

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Fig. 4

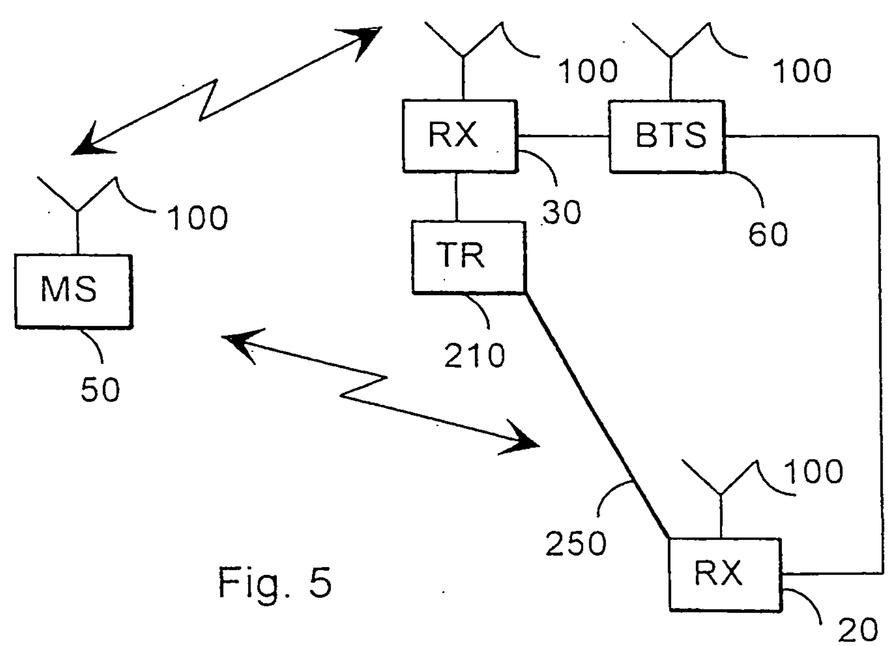
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Fig. 5

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(57) Abstract

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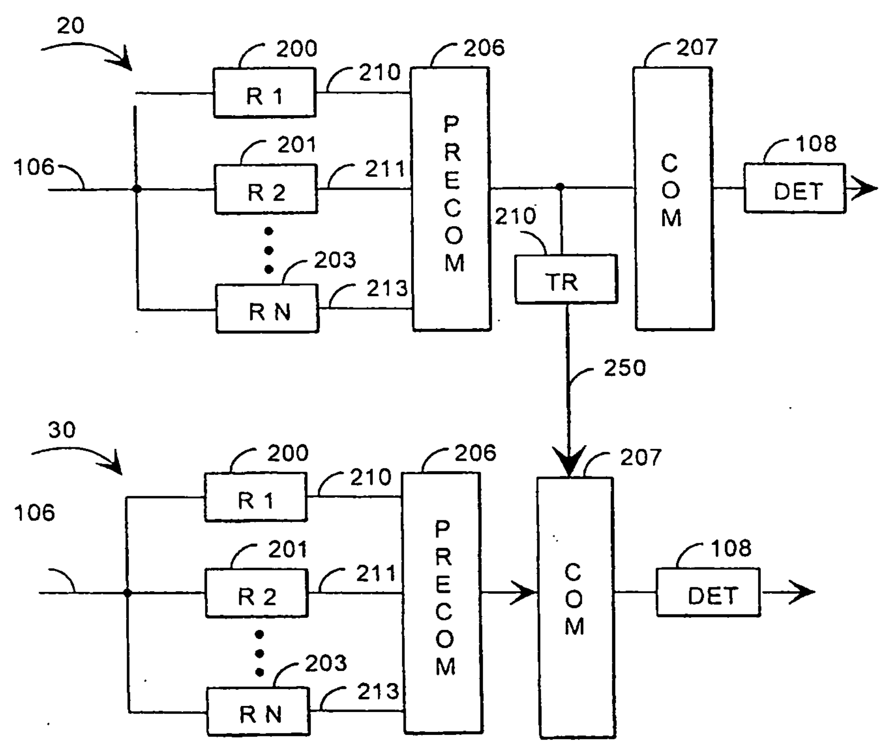

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EE	Estonia						

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00203

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04B 7/08, H04Q 7/30, H04L 1/02, H04Q 7/38
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04B, H04Q, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9700562 A1 (QUALCOMM INCORPORATED), 3 January 1997 (03.01.97), page 12, line 1 - line 4; page 14, line 15 - line 20; page 15, line 19 - line 25, page 15, line 32 - line 38, page 16, line 1 - line 8, page 16, line 21 - line 34 --	1-17
A	US 5325394 A (E. BRUCKERT), 28 June 1994 (28.06.94), column 8, line 50 - line 55; column 9, line 30 - line 56 --	1-17

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 October 1998	09 -10- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Per Källquist Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00203

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 5594755 A (A.P. HULBERT), 14 January 1997 (14.01.97), column 2, line 47 - line 51, figure 2, abstract	1,2,4,5, 7-14,16
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A	DE 19509601 A1 (SIEMENS AG), 26 Sept 1996 (26.09.96), page 3, line 30 - line 35, figure 5, abstract	1,2,4,5, 8-14,16
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A	US 5602833 A (E. ZEHAVI), 11 February 1997 (11.02.97), column 2, line 33 - line 50; column 3, line 1 - line 2; column 12, line 52 - column 13, line 4, figures 2,9, column 13, line 17 - line 39, column 15, line 5 - line 7, column 25, line 46 - line 48	1-17
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P,A	WO 9729602 A (M. OLKKONEN), 14 August 1997 (14.08.97), page 2, line 3 - page 6, line 14; page 3, line 16 - line 22	1-5,10-14,16
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INTERNATIONAL SEARCH REPORT

Information on patent family members

27/07/98

International application No.
PCT/FI 98/00203

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